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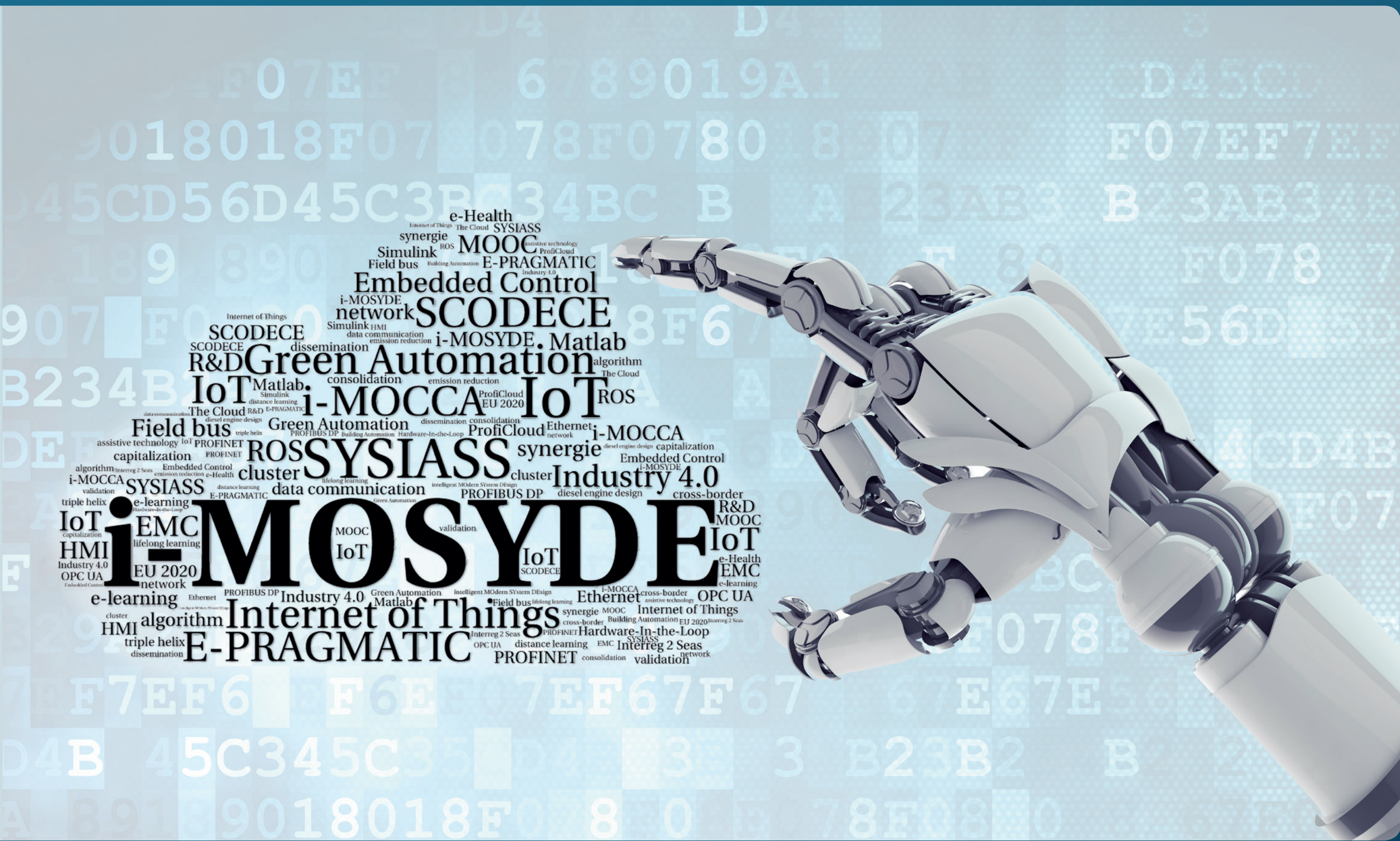

A cluster initiative:

"Industry 4.0", "Internet of Things", "Green Automation", "e-Health", "e-Learning", towards an evolution or revolution in MOdern SYstem DEsign?

2 Mers Seas Zeeën
INTERREG IV A
FRANCE - ENGLAND - VLAANDEREN - NEDERLAND

Programme de coopération transfrontalière 2007-2013 cofinancé par le **FEDER**
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Michel Delbaere

Our economy and our society are evolving very quickly, trying to be competitve worldwide and at the same time facing large sociological evolutions.

Worldwide competitiveness of our industrial economy will – besides having an appropriate basic economic climate and having high-end infrastructure – rely strongly on smart growth towards a more digital and sustainable society.
Guiding our society through the sociological evolutions already happening, will – besides realizing inclusive growth - rely on e-Health, assistive technology, e-learning, telework, … so also on a more technological and digital society.

Fostering knowledge, innovation, education throughout the working career, … and actively working towards a digital society are key actions to keep our regions where they are now, in the leading – both in the EU and worldwide – group of regions.
Regional efforts and developments are important, and so are the interregional relations and coordination. Interreg in general, and Interreg 2 Seas in particular, has set the standard for improving and enabling interregional cooperation, and is in the period 2014-2020 fostering among others an economically competitive and sustainable 2 Seas area. Flanders will actively participate in the programs and projects, and will – in cooperation with the neighbouring regions – take a step forward.

The clustering Interreg 2 Seas and Leonardo da Vinci projects within the i-MOSYDE project have proven to be efficient, and yielded a lot of direct (scientific-technological) results for our industrial economy and our society. Results range from R&D via courses and facilities for lifelong high-end learning to proof of principle demonstrators in university labs and applications in industry.
In the transition towards the digital society, and more specifically to "Industry 4.0", the "Internet of Things", e-Health and assistive technology, …, cluster initiatives like i-MOSYDE successfully capitalized on the knowledge acquired, and took a first step in defining the next initiatives necessary for the evolution towards a smart, competitive and inclusive society.
I wish them all the best for the future!

Michel Delbaere,
Chairman of Voka Flanders

Introduction

Both the West European industry and the services are moving to a crossroad nowadays. Europe needs to find a solution to the long-term challenges such as globalization, pressure on resources, and ageing populations.

This forces us to make an important decision. Will we continue in the same direction or will we change our way of working and thinking? The keyword for new jobs, global competitiveness and increasing employment is “smart”, smart factories, smart health, smart mobility, … To become “smart”, the enabling technologies are mainly electronic devices – all communicating with each other (the “Internet of Things”) – and new algorithms working with all the gathered data to create optimized production (fast, green and tailored for every customer), optimized health (preventive monitoring and assistive technology), and optimized mobility (green mobility, traffic guidance and automated driving). All these technologies need a huge number of training courses, involving hands-on laboratories, combined with e-learning and pilot installations.

This new way to develop the economy of the future joins the new strategy of Europe, called Europe 2020 aiming to prepare the EU economy for the next decade. The European Commission has identified three key drivers for growth, which will be supported through actions at both EU and national levels: smart growth (fostering knowledge, innovation, education and digital society), sustainable growth (making EU production greener and more resource efficient while boosting competitiveness), and inclusive growth (enhancing labour market participation, skills acquisition, and the fight against poverty).

Four projects worked the last 4 years independently of each other on different topics, concerning assistive technology, industrial data communication, e-learning courses and sustainable energy technology. 3 projects are regional ones, working in the Interreg 2 Seas area. 7 partners out of these 4 projects joined forces in the cluster project i-MOSYDE. Cluster projects are besides territorial clusters mainly thematic clusters. The aim of the cluster is consolidating, valorising and disseminating the project results, in order to increase the impact of the individual project results. The different technologies and used methods are interesting for all partners and will be a step forward to new developments in the future.

The cluster partners exchanged their knowledge on current developments regarding embedded systems, mobile applications, data communication and learning tools. They exchanged information on “lessons-learnt”, occurring problems, implemented solutions, and discussed future developments. Choosing for “smart” will involve different technologies, discussed in this text.

This publication contains three major parts. The first part discusses the achievements of the different clustering projects and the relation to the EU2020 context. The second part looks forward to the expected fourth industrial revolution, “Industry 4.0”, and the related (Industrial) “Internet of Things”. Some key enabling technologies are described in this part. The third part focuses on these key technologies and how these were already used in the different projects.

CHAPTER 1

Who we are – EU 2020 – General lessons learnt

1.1 Who we are – The contributing projects

The i-MOSYDE acronym (intelligent MOdern SYstem DEsign) is also composed of the 4 clustering projects: i-MOcca, SYSiass, scoDece, E-PRAGMATIC.

This paragraph briefly describes the key data (Fig. 1) and the topics addressed in each of the clustering projects.

1.1.1 SYSIASS

SYSIASS (Autonomous and Intelligent Healthcare System) aimed to address a range of technological barriers currently inhibiting the uptake of new technological advances within the healthcare professions in the Interreg IVA 2 Seas regions, with a special emphasis on technology related to the provision of effective and

Project	i-MOCCA	SYSIASS	SCODECE	E-PRAGMATIC
Budget (M€)	4,466	2,460	1,162	0,510
Funding by	Interreg IVa 2 Seas	Interreg IVa 2 Seas	Interreg IVa 2 Seas	Leonardo da Vinci (Lifelong Learning Programme)
ERDF (50%)	50	50	50	75
Duration (months)	39	43	40	24
LP	KU Leuven	ISEN-Lille, France	HEI, Lille, France	University of Maribor, Slovenia
Consortium	Ugent, Univ-Lille 1, Un. of Greenwich, ISEN-Lille, ICAM, HEI -Lille	Ecole Centrale de Lille/ CNRS, Un. of Kent, Un. of Essex, East Kent Hospitals Un. NHS Foundation Trust, Groupe Hospitalier de l'Institut Catholique de Lille	Un. Jules Verne Picardie, Un. of Sussex	B2 d.o.o., Ljubljana, Slovenia; ECPE Nurnberg, Germany; Un. of Deusto, Fac. of Eng., Bilbao, Spain; Poznan Un. of Techn., Poznan, Poland; Carinthia Un. of Applied Sciences, Spittal/ Drau, Austria; Delft Un. of Technology, Delft, The Netherlands; Chamber of small business and craft (electronics and mechatronics), Slovenia; Elson Electrónica S.A., Zamudio, Spain; Simulation Research, Alphen aan den Rijn, The Netherlands; Wielkopolska Chamber of Commerce and Industry, Poznan, Poland; Flowserve Control Valves GmbH, Villach, Austria; ALFEN, the Netherlands; Höhere Fachschule für Technik, Mittelland Biel, Switzerland; Siemens Schweiz AG Industry Automation and Drive Technologies, Switzerland

Figure 1. Key data of the clustering projects.

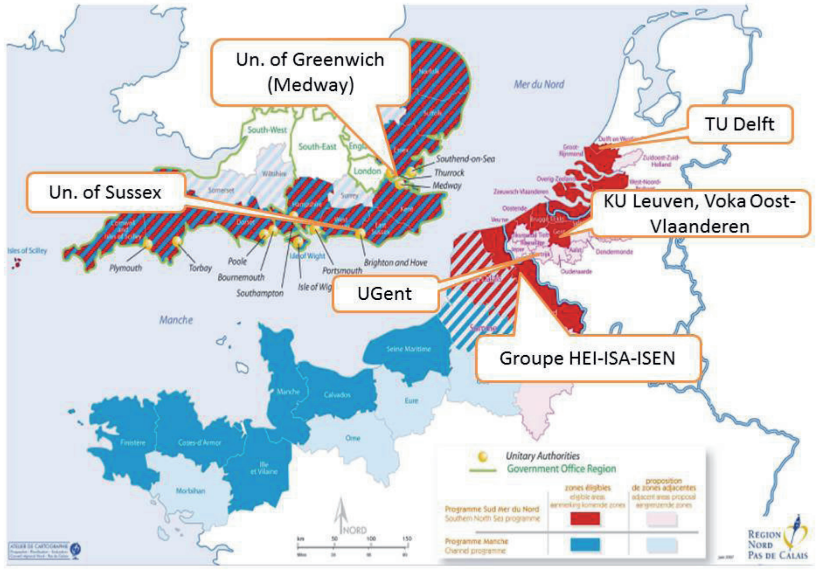


Figure 2. Safe navigation device plugged into Dupont Medical and Invacare powered wheelchairs.

safe powered mobility. Preserving the autonomy of the disabled and elderly is indeed a major issue in today's society. In Europe, with the progressive ageing of the population policy to support the elderly is increasingly based on the assumption that care must be provided efficiently to the patient where he is based. In addition, special attention is devoted to people with disabilities for their better integration into society, knowing that in 2009 only 65% of disabled people were employed[1].

The goal of the project was both the design and the implementation of new assisted navigation devices and hands free human-machine interfaces for a powered wheelchair (Fig. 2) taking into account the user's needs and their specific cognitive abilities. These devices must be adaptable to meet the specific needs of the user and interfaced with any commercially available powered wheelchair. The devices were evaluated by the users through clinical trials.

www.sysiass.eu

1.1.2 SCODECE

Diesel engines can now run on fuel which is less polluting. HEI (Hautes Etudes d'Ingénieur) set up a research project called SCODECE (Smart Control and Diagnosis for Economic and Clean Engine) with two partners, the University of Sussex and the University of Picardie - Jules Verne. SCODECE aims to optimize Low Temperature Engines (LTC) which consume less fuel, whilst maintaining a level of efficiency that guarantees the same or superior performance level, enabling the engines to be less polluting and more reliable. The project included the development of a test bed that served as both an evaluation platform for users and a virtual simulator for replicating the engine's functions and malfunctions. The research results clearly respect the environmental requirements and this is achieved by using new control strategies as one of the key demands on modern combustion technologies. With our expertise and experience, advanced controllers have been designed and implemented on the CAT3126B engine test bed for improving LTC diesel engines by integration with variable valve timing (VVT).

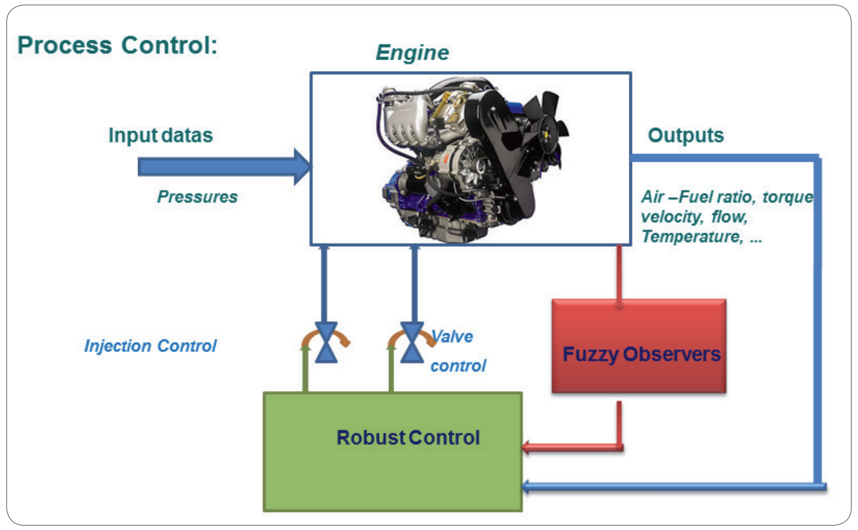


Figure 3. Overview of advanced robust control scheme designed in the SCODECE project.

1 http://www.disability-europe.net/content/aned/media/ANED%20Task%206%20final%20report%20-%20final%20version%2017-04-09.pdf

The demonstrator (Fig. 3) is ready to continue to test new controllers and new approaches in diagnostics. The three partners have created a transnational network likely to attract other partners in the future.

www.scodece.org

1.1.3 i-MOCCA

i-MOCCA – interregional MObility and Competence Centres in Automation – intensively worked on two important enabling technologies in automation: industrial data communication and embedded control. Both are rapidly changing technologies, needing a lot of high-end training, and requiring demonstrators and proof of principles to "push" these technologies into industry applications.

i-MOCCA ...

- Set up a network of competence centres in control and automation labs in KU Leuven (Technologiecampus Gent, BE), UGent campus Kortrijk (BE), Univ-Lille 1 (Lille, FR), Un. of Greenwich (Chatham campus, UK), Groupe HEI-ISA-ISEN (ISEN-Lille and HEI-Lille, FR), and ICAM (Lille, FR). These centres use the same basic equipment, allowing easy exchange of staff, ideas and experience, and course and demonstrator materials. They add own specific local technologies and specialities, enriching the experience of the project group.
- Designed and taught workshops, lectures, short and long (up to 4 day) hands-on courses, targeted to practicing engineers in industry. For design, feedback, and realistic experiments, intensive cooperation with industry and professional organizations was mandatory.
- Realized lab demonstrators and "proof of principles", and industrial applications, to "push" new technologies towards industry.

Preliminary results (Fig. 5) include 25+ workshops (half or full day, 700+ industry participants), 30+ lectures (between 20 to 60 minutes, 650+ industry

Figure 5. Both i-MOCCA and E-PRAGMATIC tried to push new technologies towards industry, among others by designing and teaching workshops and long courses for industry.

Embedded control

"Embedded systems" are electronic systems (software, hardware, communication possibilities) integrated in all kinds of devices (e.g. a smart phone). The embedded software introduces flexibility and allows updates. "Embedded control" is the industrial version: measurement, control and data communication are all in one system. Recent (and ongoing) developments facilitate direct generation of real-time program code from R&D Matlab/Simulink software for industrial hardware, which has direct access to industrial communication networks such as Profibus and Profinet. This allows design, rapid prototyping and final production software and hardware to be realized in one working environment.

Within the clustering projects, applications have been developed for diesel engine control (see 3.2.1), for LEGO mobile robotics, for a demonstrator on embedded control combined with industrial networks (see Fig. 4), ...

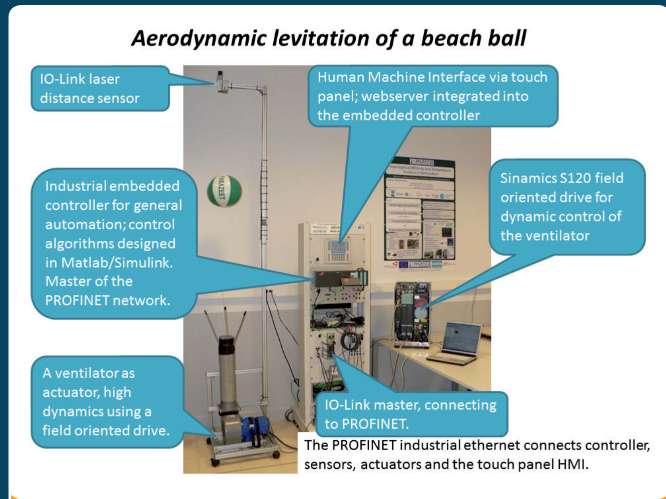


Figure 4. The aerodynamic levitation of a beach ball is an eye-catching demonstrator combining embedded control (the control system is designed and the program code is generated by Matlab/Simulink) on an industrial hardware target, with all sensors and actuators connected via Profinet and IO-Link industrial data communication networks.

participants), 7 intensive courses (typically 4 day, 50+ industry participants), 20+ MSc thesis projects, 10+ papers at scientific conferences, … and intensive staff mobility. Master students in engineering were also included in a number of activities. In total, 300+ companies took part in at least one activity.

www.imocca.eu

1.1.4 E-PRAGMATIC

Fast technological progress requires from technicians and professionals in industry to constantly refresh and update their professional knowledge. Comprehensive e-learning modules, which meet the knowledge needs and are integrated into conventional in-company training, can meet those needs. E-PRAGMATIC network was established in order to develop the approach and provide suitable e-learning modules. The network is an association of 13 regular and 7 associated partners from nine European countries. Included are educational institutions and end users such as chambers, enterprises and associations of enterprises.

To ascertain concrete knowledge needs and education habits of professionals from electro-mechanical industry a comprehensive international needs analysis was conducted. Data was collected by e-survey and interviews with enterprises' management. Country-related and overall analyses of the current state were prepared. Next, an integral concept for training in electro-mechanical industry in the area of mechatronics and alternative technology was developed. This innovative concept is based on four elements: learning management system/portal for industrial training; model for presentation of learning materials; andragogical[2] educational approach; training modules and programs. The concept applies distance training by using multimedia e-learning materials and remote experiments. Self-directed learning is supported by intensive mentoring. The concept was evaluated by conducting an international pilot training; participants were mostly employees from industrial partners and employees from other companies from this field. Results of development are used by the industrial partners in their in-company training and by the educational partners for their regular teaching. Integral industrial training concept can be also used in other technical fields.

www.e-pragmatic.eu/

1.2 EU 2020 strategy – National and regional policies

The EU 2020 strategy – reflected in regional and national policies – aims at[3]

- 75% employment of the 20-64 year-olds
- 3% of the EU's GDP[4] to be invested in R&D
- 20% less greenhouse gas emissions compared to 1990, 20% of energy from renewables, and 20% increase of energy efficiency
- Reducing the rates of early school leaving below 10%, and at least 40% of 30-34 year-olds completing 3rd level education
- 20 million people less in or at risk of poverty and social exclusion.

National and regional policies support this strategy, adding specific accents. Moreover, the European Commission set as goal a 20% contribution of the manufacturing industries in GDP[5]. As manufacturing industries indirectly multiply their effect (employment in services, high contribution in R&D, large contribution expected for energy efficiency and greenhouse gas reductions, …), these industries constitute a large % of the total economy[6]. The contributing cluster projects and partners are all heavily supporting these aims in their projects.

Within (the projects clustering into) i-MOSYDE, several of these aims are researched, and are in line with EU2020 and other EU, national or regional initiatives. Some examples:

- FP7 AAL is about "ambient assisted living", the main component of the SYSIASS project, developing technologies for powered wheelchairs (PWC), **enabling inclusion of people with disabilities** in society and working environment.
- The underlying control and automation of these wheelchairs are basically the same as used in i-MOCCA, SCODECE, and some of these topics are courses within the E-PRAGMATIC project.
- Especially i-MOCCA and of course E-PRAGMATIC not only support **lifelong learning**, but also involve engineering students and influence/support e.g. MSc curricula. The topics addressed are of large importance for the **research** and **development** in the manufacturing industries (e.g. industrial data communication, embedded control, etc), in "green automation" (e.g. ProfiEnergy, building automation systems (BAS), …), in renewable energy, … . Interreg IV A 2 Seas resp. Leonardo da Vinci funded these projects. The new education strategy belonging to EU2020 programme continues to promote **the cooperation for innovation and the exchange of good practices**, by supporting cross-institutional and cross-sectoral exchange and partnerships between education and training institutions and the "world of work" which was the core of both i-MOCCA and E-PRAGMATIC.
- The more efficient diesel engine design developed in SCODECE is of direct importance for **decreasing greenhouse gas emission** and increasing energy efficiency; at the same time, it uses the same technology (simulation, followed by code generation for embedded control, …) as other i-MOSYDE partners. E.g. the UK Low Carbon Vehicle Partnership (LowCVP) actively supports this R&D, part of the EU's aim to reduce greenhouse gases by 20%.

Chapter 3 shows a number of results, illustrating the broad impact of these technologies.

2 Andragogy" interpreted as "the art and science of helping the adults to learn".

3 http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/targets/index_en.htm

4 Gross Domestic Product.

5 D. Herbert, acting Dir-Gen. at EU, in Trends, 29/05/2014, p. 26-29.

6 This important goal is discussed for each Interreg 2 Seas region later in this chapter.

The EU2020 aims and technologies are of course interrelated and mutually reinforcing.

- Educational improvements (lifelong learning, impact on engineering education by having up-to-date and R&D supported curricula, …) support employability throughout the (working) career. Introducing new technologies (by proof-of-principal demonstrators (Fig. 4), pilot installations, workshops, …) and more R&D make our economy more competitive and thus create (or keep) jobs.
- Interaction between EU regions and cross-border cooperation of universities, competence centres, governments, industry, professional organizations is of the utmost importance: this interaction also reinforces the efforts to be made towards a more competitive economy and more social society. This interaction is typically depicted in a "triple helix"[7]; some of the major interactions that are typical for both the clustering projects and the cluster itself can be found in Fig. 6.

7 "Industry and engineering education interacting in an interregional project – a Flanders' perspective", SEFI 2014, Sep. 15-19, Birmingham (UK). Jos Knockaert, Geert De Lepeleer, Tony Stevens, Philippe Saey.

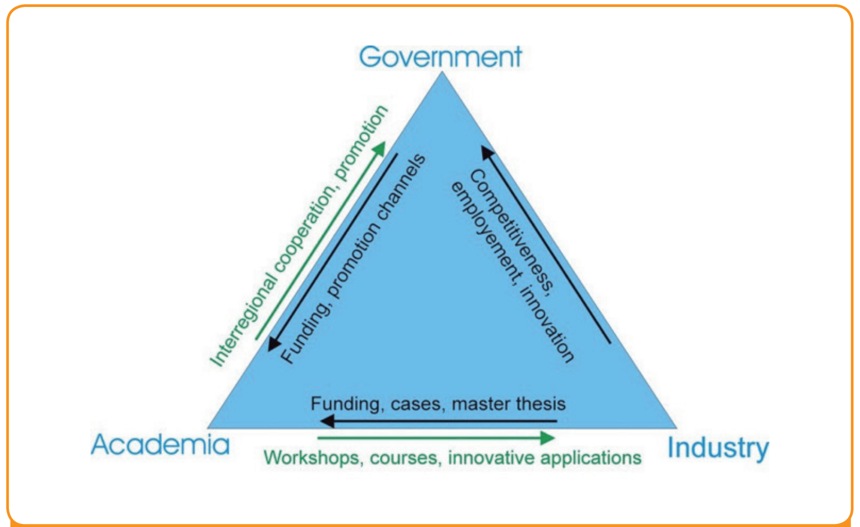


Figure 6. Triple helix applied to typical interactions in the cluster(ing) project(s).

1.3 Lessons learnt – General capitalization results

In the capitalization phase of i-MOSYDE, we found parallels and accents, and concluded on a number of general lessons learnt. Chapters 4 and 5 describe capitalization results with regard to technological-scientific themes, and some applications and beneficiaries. This chapter describes the capitalization of more general themes: some conditions to make a successful interregional cooperation in a EU project, different ways to get interaction with economy and society.

Sharing resources is important; for technological-scientific projects this generally means working with the same equipment and software. This varied between cluster projects from using the same professional software (for SCODECE AMESim for hardware in the loop simulations, Matlab and Simulink for simulation, analysis and design) to the same eCampus learning management system (E-PRAGMATIC).

Designing and testing algorithms for assisted navigation devices for Power Wheel Chairs (PWC) was only possible using the same low-cost sensors and embedded computers plugged into a commercial PWC.

i-MOCCA took this practice to an even higher integration, defining already in the preparation phase (prior to the project approval) basic hardware and software, and jointly purchasing this to obtain better prices. During the many cross border internal conferences, tech-

Towards a new industrial economy in France

France[1] has the ambition to become a high-tech, innovative economy, and is hedging bets over several technologies with substantial long-term risk-sharing investment.
The strategic axis of the "new industrial France" defined by the French ministry of Industry in 2013, aims to consolidate the existing industries as well as to focus the investments on new key technologies for the long term, especially in those proposing breakthrough innovation for the energy and environmental transition, the healthcare and the digital solutions. Among the technological fields trends worth supporting we could find the transports (including the development of low consumption cars and/or automated driving, new electric aircraft, the future TGV), robotics, connected objects, smart factories, …
Significant emphasis is given to the development of French industrial offer in e-health, e-learning, connected objects, or the contactless services and augmented reality."

1 http://www.economie.gouv.fr/nouvelle-france-industrielle

Towards a new industrial economy in the United Kingdom

The UK Government[1] is committed to supporting the UK electronics industry which has the opportunity to develop its strong position to become a world leader across a broader range of electronic technologies. Priorities for the sector include: addressing the sector's skills challenges, taking a leading role in the area of Industrial Automation through the Industry 4.0 initiative, accelerating growth in other UK sectors through the use of UK electronic systems in their supply chains, and capitalizing on the potential growth opportunities offered by the Internet of Things. For example, in the automotive sector, the Automotive UK Council has identified among the key challenges both the training for and the development of technologies. It is important to support companies to continuously up-skill their people, but also to develop more intelligent, lower carbon and highly efficient mobility solutions for the 21st century.

1 Industrial strategy, Government and industry in partnership, Progress Report, April 2014

Towards a new industrial economy in Flanders

By 2020, Flanders[1] wants to excel as an economically innovative, sustainable and socially caring society. The Government of Flanders and all the important social partners have established these objectives in the Pact 2020. Among the 13 themes defined by the programme VIA (Flanders in action) we could find some related with the topic of this publication: Flanders' Care, Mobility - Smart Mobility, Talent - Everyone Participates, Everyone is Active, Energy - Renewable Energy and Smart Grid, New Industry - New Industrial Policy.
The Flemish government creates opportunities for the Flemish citizens to think, live, work, coexist and do business differently. It encourages a more effective Triple Helix of university-industry-government relationship to make it possible to find solutions to face the great challenges that lay ahead like the energy issue, the ageing of our population or environmental and mobility issues.

1 http://www.vlaandereninactie.be/en

Towards a new industrial economy in The Netherlands

In the Netherlands[1], there are 9 top sectors having a strong international position. Industry and science share a wealth of knowledge and jointly develop innovations. The development of new greener innovative solutions or smart solutions by using the new communication technology is strongly encouraged by the Dutch government through the energy and high tech sectors. The implementation of the action plan promotes, as in Flanders, the golden triangle principle (collaboration between the industry, knowledge institutes and the government).

1 http://www.government.nl/issues/entrepreneurship-and-innovation

nical days, workshops, etc., there was immediate and in-depth understanding of practical concepts and solutions, and it was easy to exchange practical tips, solutions and workarounds. Moreover, staff mobility was a lot easier, as only programs and some specific equipment – as every project partner had its own specialization – needed to be transported to other partner universities for courses and workshops.

Short distances between project partners also facilitate successful cooperation: being able to travel by car (and in short time) made it possible for SYSSIAS to use PWC improved on one site for clinical tests on another site. In i-MOCCA, it also allowed to have short one day student exchanges for workshops, introductory courses, giving students a jump start for project work, or to visit e.g. working BAS (Building Automation Systems), which are of course not transportable.
In general, short travel times make meetings (both project wide or partner-to-partner) easier to fit into busy agendas.
E-PRAGMATIC is logically the exception: not being an Interreg 2 Seas project but a Leonardo da Vinci project with partners in many EU countries, distances between project partners was larger and the number of meetings more limited. However, partners inside one country organized themselves to jointly work and test courseware.

Interaction with users to obtain knowledge on themes experienced as important by the targeted audience, or technologies to be covered, or to get user feedback, were found to be diverse and complimentary. E-PRAGMATIC started the project in a 1st phase with a needs analysis (e-surveys, direct interviews, …), developing courses, multimedia materials and virtual or remote experiments in a second phase. This inevitably led to a long trajectory to "market", in this case to present the e-courses to the distance learners themselves.
i-MOCCA worked intensively with professional organizations, already having the knowledge of user needs, in the preparation phase prior to the actual project. Consulting a number of companies having a lot of experience and/or needs, also provided useful information in a short time frame before applying for the project. This lead to more detailed planning of equipment needed, duration of trainings, … already in the application form, leading to a quick start.
For the design of assistive technology for powered wheelchairs, SYSSIAS built on two tracks: the first was to quickly identify scenarios (degrees) of assistive technology from less complex to more complex, allowing to have quick first "success stories" to be shown and to communicate about. Quick communication helped attracting disabled persons for testing the technology, and also enabled identification of the degree of assistance the user (disabled person) wants.

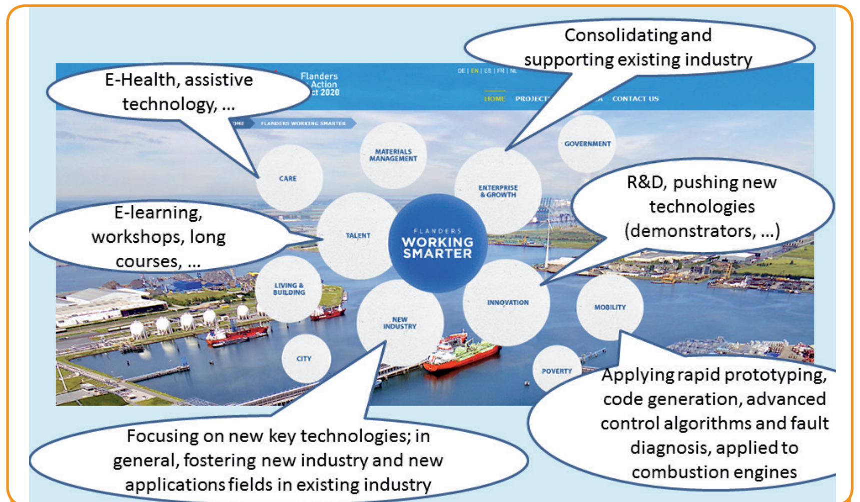


Figure 7. How the cluster contributes to developing the industrial economy in the member states.

Within Phase 1 of the cluster itself, a mixture of meetings, questionnaires, lectures on meetings, lab visits, … all have been used to familiarize with the partners and clustering projects, and to identify parallels and to valorise opportunities.

All clustering projects had project partners with *complementary knowledge and experience*, leading to more and more in-depth results. i-MOSYDE itself is – as a cluster project – also formed with 4 projects, quite a large number, allowing very diverse input and application fields. It has to be stressed, however, that the nature of the technologies and knowledge used can be applied in very diverse fields, from e-health and assistive technology over engine (controller) design to building automation systems and to highly complex large scale manufacturing industries. Cross-pollination between such diverse application fields this way is almost natural.

The i-MOSYDE project partners got assistance, ideas and help from *professional organizations and networks* not only for communication purposes, but also to reach users and beneficiaries, to get in-depth or vendor-specific knowl-

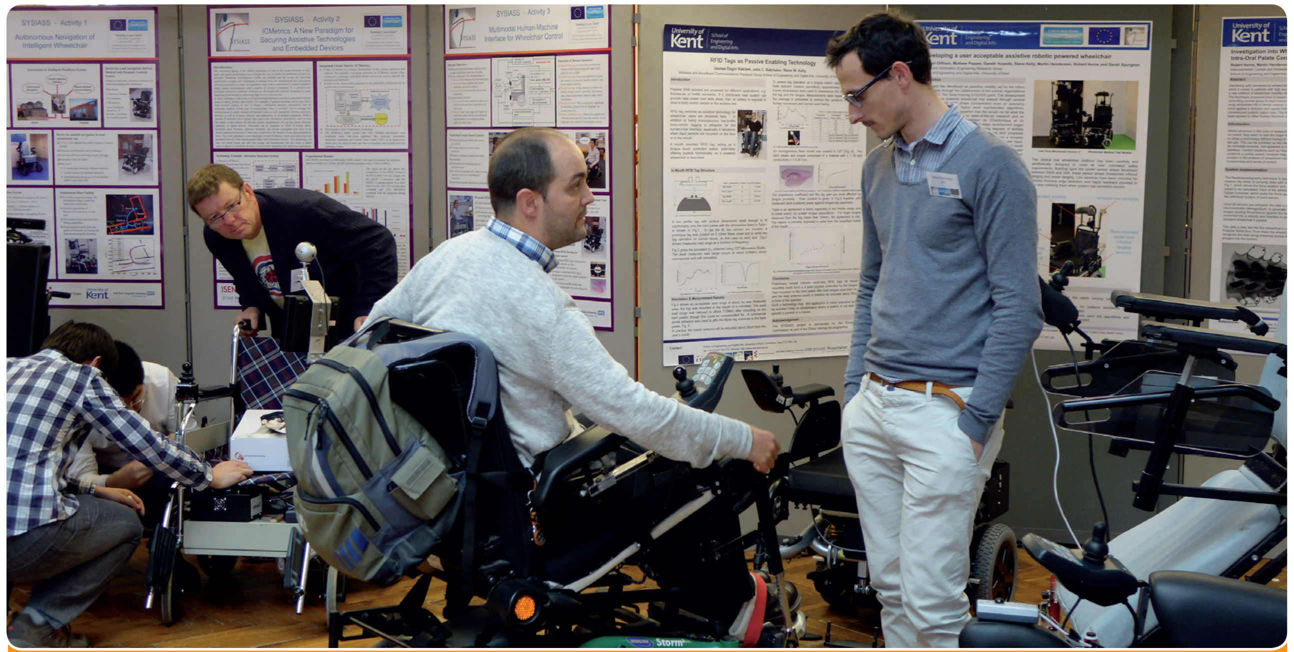


Figure 8. Discussion from within the design phase and direct feedback from the end user of assisted navigation with powered wheel chairs.

edge. By the nature of the project – distance learning – E-PRAGMATIC reached a lot of users via the Internet. The cluster expects this channel to grow quickly, even for attracting "regular" students. In a MOOC – a Massive On-line Open Course – on PV[8], TU Delft reached about 40.000 on-line students; as an important side-effect, several tens of MSc students from all over the world enrolled in a MSc study after taking the MOOC[9].

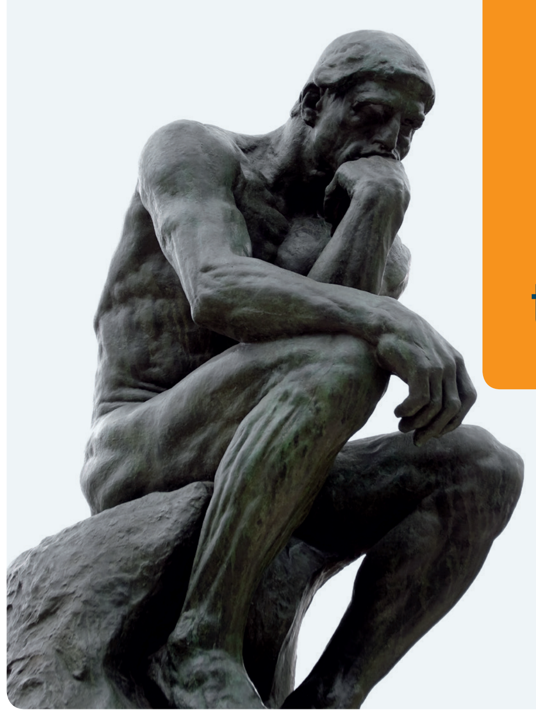
8 PV: PhotoVoltaics ("solar cells").

9 "Transforming our engineering education: MOOC (Massive Open On-line Course) on PhotoVoltaics", Arno Smets, TU Delft. Lecture on the "Industry 4.0 talks!", 21/10/2014.

"Being able to test early in the project lead to the conclusion that – depending on the cognitive abilities and on the age of disabled persons – users of assistive navigation devices wanted devices for safe navigation, for semi-autonomous assisted navigation, or for safe navigation with autonomous door passing." Annemarie Kokosy, Project Manager SYSIASS

Conclusions

- Enable sharing knowledge and obtaining results quickly by using the same basic equipment and software.
- Go for project partners at short travel distances/times from each other, or go (almost) completely digital (virtual).
- Obtain interaction with your users as soon as possible in your project: in the preparation phase if possible, or – if the end user needs to test designed equipment – after having made basic (quick to implement) test rigs in the project start-up phase.
- Continuous education and training is necessary; have your users, people taking workshops or courses, … give (short) feedback.
- Go for cooperation with professional organizations, allowing more easy communication to the beneficiaries, identifying needs, attracting users, … .



CHAPTER 2

Industry 4.0 & Internet of Things – Enabling technologies – i-MOSYDE

The i-MOSYDE cluster identified a number of technologies used in one or more contributing projects: (wireless and mobile) data communication, robustness of networks, HMI (Human to Machine Interface), E-Learning, Model Based Design, Embedded systems and controllers. These will be briefly discussed in this chapter. These technologies combined and developed even further, are the main constituents of Industry 4.0, the Internet of Things, Smart Factories, Assistive Technology and e-Health, … This chapter first describes these new paradigms: Industry 4.0, Internet of Things, … . As already mentioned, the technologies jointly assessed in the cluster (and clustering projects) are then described in short.

The Internet of Things (IoT) is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure. All these embedded computing devices communicate data. The Internet of Services (IoS) is a multitude of connected IT services, which are offered, bought, sold, used, repurposed, and composed by a worldwide network of service providers, consumers, aggregators, and brokers. In short, it results in a new way of offering, using, and organizing IT supported functionality

2.1 Industry 4.0 – Internet of Things … "hit or hype"?[1]

Industry 4.0

Industry 4.0, named after the upcoming fourth industrial revolution, will radically reform the manufacturing industry in Europe and make it more competitive. The three previous industrial revolutions were driven by the mechanization of production by using steam (first industrial revolution), the mass production by using electricity (second industrial revolution)
and the thorough automation of production using IT and electronics (digital revolution). The base of the fourth industrial revolution is formed by the so-called Internet-or-things (IOT) and by man-machine combinations.
Industry 4.0 enables the development of Smart Factories, looking at production in a completely different way. In Smart Factories, production and logistics are working autonomously and are controlled by individual intelligent objects. Machines communicate with each other, trigger each other's actions and make optimized decisions based on complex algorithms.

1 We borrowed the "hit or hype" expression from the i-MOSYDE cluster conference lecture "Industrie 4.0 - Hit or Hype?", by Martin Krüger of ABB.

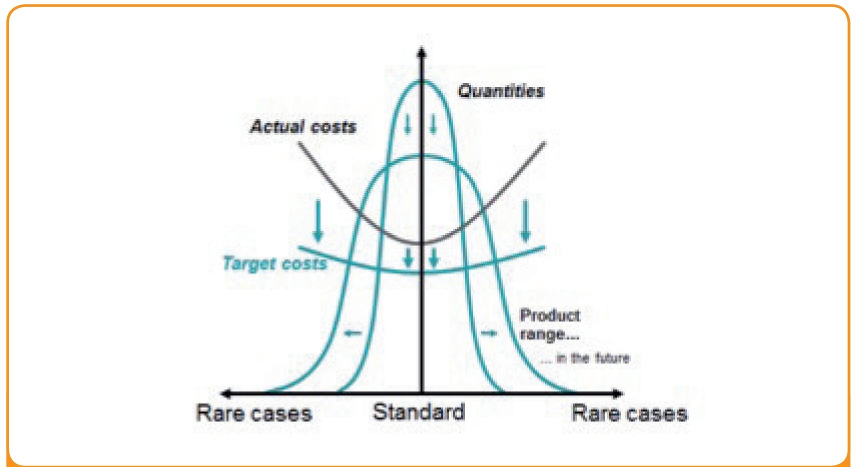


Figure 9. Requirements and evolutions expected to become realized in the years to come.

Reference: "Industry 4.0 – Key aspects and future Development", lecture by H-J. Koch and F. Knafla (Phoenix Contact) on the i-MOSYDE cluster conference on 21/10/2014.

The purpose of this development is manifold. The future manufacturing industry will not create mass products, but unique products. The production can be directly adapted for each finished product, so that each finished product is directly tailored to the client. The necessary supplies, the necessary energy and the necessary manpower can be adapted to the foreseen production. Development time and production time of end products decrease. As a result, energy-efficient, high performance and competitive factories are created, being able to meet the requirements and the evolutions illustrated in Fig. 9.

The systems and components themselves monitor various parameters so that predictive maintenance can be requested automatically.
For the employee, the ergonomic position is optimized. A continuous monitoring of the health using (body) sensor networks and flexibility in production ensures better working conditions and improves the balance between work and family life. Assistive technology and service robotics helping disabled persons enforce the integration of certain groups in the workplace. Industry 4.0 allows plants to evolve to intelligent individual systems that combine to form a completely optimized unit. A worldwide network of connected systems makes this possible, thus fading the boundaries between individual plants. Roadmaps predict that Industry 4.0 will be operational in 10 to 15 years. Industry 4.0, which originates in Germany, is also for the rest of Europe a step that should not be missed. It will take many years of research and a completely new approach of the manufacturing industry. The challenges are not found regarding the technology itself. The necessary technology is commercially available or "in the pipeline". The difficulty lies in bringing together all aspects in order to get a collaborative and fully optimized entity, which fixes industrial and social problems. For a successful implementation, research is therefore needed in the following fields[2]:

1. Standardization: the optimization of a "network" between different, originally independent, factories requires a common "language".
2. Control of complex structures: individual systems that work together to create a final product are already complex. The boundary conditions, such as logistics, energy efficiency, maintenance, require models in order to optimize the full system. In addition, software should be developed to implement the optimized algorithms in the workplace.
3. Communication network: the key technology for the entire industry is an efficient communication platform. Given the size of the data, a broadband and widespread network is required.
4. Safety and security: Data networks are fragile and need to be appropriately protected against external influences. Examples of problems include unauthorized access, interception of data, changing of exchanged information and the influence of external electromagnetic interference. Also, users should be able to work safely in an environment dominated by thinking machines.
5. Education: Smart factories ask for employees with other responsibilities. Training and lifelong learning is necessary. The complexity requires digital learning environments and simulated environments.
6. Legal implications: the new working methods, exchange of data, the cross-factory and cross-border cooperation require a thorough juridical review.
7. Efficient use of natural resources: Industry 4.0 represents a major change and requires a lot of resources and energy. This is in contradiction with the end goal of this revolution namely to be economical with the available resources in the production. A profound cost-benefit analysis is necessary.

2 Reference: "Securing the future of German manufacturing industry - Recommendations for implementing the strategic initiative INDUSTRIE 4.0 - Final report of the Industrie 4.0 Working Group", April 2013.

"The bottleneck is not really the technology; the fundamental components or "things" are all there. What the market needs is more industry innovators who can put the technology together in unique ways that will solve specific industry problems."
Paul Howarth, Cisco.

Within the production horizontal and vertical integration of IT is established. Horizontal integration refers to the implementation of IT in all phases of the production process, starting with the suppliers (both raw materials and energy) and ending with the outgoing quality control and after sales service. At Industry 4.0 such integration includes interconnected smart objects, so that the entire chain can be controlled and optimized. Vertical integration of IT stands for implementing IT in all levels, from smart sensors, smart actuators and smart machines to smart factories.

Internet of Things

The Internet of Things allows everything and everyone to be connected. From small sensors to large machines, everything can communicate. The technologies, making this possible, are embedded systems, wireless and mobile communications and networks and the existing Internet structure. For applications, the development of MEMS (micro-electromechanical systems) and the processing of so-called "big data" is also important. It is estimated that by 2020, 30 billion devices will be connected to the Internet and will be able to communicate with each other. The wireless interconnection, the embedded systems and the algorithms provide "Smart Products". The applications are numerous and some are already commercialized. Examples are the smart watch with various sensors to monitor the health of the individual, environmental sensors that monitor water quality and air quality, sensors on buildings, bridges, off-shore wind turbines. The industry also joins this trend, talking about the Industrial Internet of Things (IIOT) leading to the previously described "Smart Factories" or "Industry 4.0". Finally, within the domestic and office environment, "Smart buildings" are the next step in the evolution of home automation. Heating, shading, cooling and consequently energy consumption can be regulated depending on the presence of the occupant, on the weather, on the availability of (cheap) electrical energy. This user is an additional actor by means of his smartphone or tablet. His domestic devices, such as the washing machine, autonomously decide when to work and communicate with the smart grid and other devices to spread the energy demand or to shift usage to economically more interesting moments.

Internet of Services

Besides the Internet of Things, the Internet of Services is presented in Fig. 10. An example is the "smart grid." The generation of electrical power shifts from centralized to decentralized. Sup-

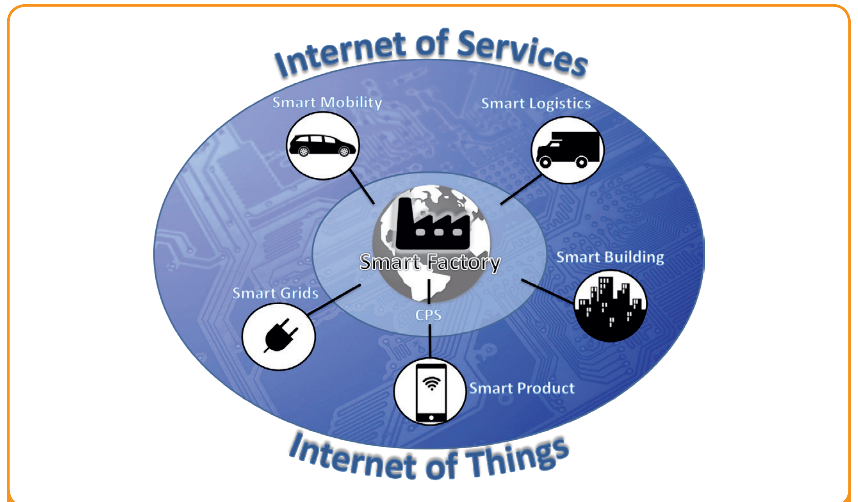


Figure 10. Overview of some of the elements of the Internet of Things and of Services.

Reference: figure based on "Securing the future of German manufacturing industry - Recommendations for implementing the strategic initiative INDUSTRIE 4.0 - Final report of the Industrie 4.0 Working Group", pag. 19, April 2013.

ply and demand in a centralized system are easy to control, but a smart grid is far more complex. The energy supply of decentralized energy is strongly weather dependent. Controlling complex interconnected systems requires communication between all elements in the energy chain, the processing of large amounts of data and complex algorithms. In a smart grid, energy consumers, energy resources and energy communicate mutually and with the energy regulator to obtain both minimal energy consumption and at the cheapest moment[3].

Another example is "Smart Mobility". Redirecting the flow of traffic is already possible, but smart mobility is a large step ahead. Electric cars indicate when they should be charged and book autonomously a charging station at the point of arrival. All this is possible without driver intervention. Additionally, for transport of goods "Smart Logistics" determine optimal routes, depending on the locations and traffic.

Towards a Cyber Physical System

A cyber physical system (CPS) combines physical objects with virtual objects. The physical object can be every real device, every "thing". The virtual objects represent the collected data, gathered by data communication networks. The virtual objects search knowledge in the cloud and visualize this data to inform and help the user. Common applications of CPS typically fall under "sensor-based communication-enabled autonomous systems". For example, many wireless sensor networks monitor some aspect of the environment and relay the processed information to a central node. CPS is the evolution from embedded systems giving intelligence to objects, to systems with a virtual counterpart. This visualizes information and adds the most up to date information from the cloud. On the other side, the virtual objects can be used in virtual models and simulations, supported by real information from real devices. This increases the reliability of the models under real conditions.

3 "Transforming our electricity supply: How is your flexibility used in the energy markets?", lecture on the i-MOSYDE cluster conference, by Bart Massin, Electrabel - GDF Suez

2.2 Key enabling technologies

The above revolutions require various technologies, which already exist individually; these technologies were used in the clustering projects and are considered important by the cluster (Fig. 11):

- (Wireless and mobile) Data communication
- Robustness of and diagnostics in networks
- HMI – Human-Machine-Interface
- E-Learning
- Assistive technology and e-Health
- Integrated Design[4]
- Embedded systems and controllers

Data communication

Within the project i-MOCCA both wired and wireless communication were examined in an industrial context. The performance of various platforms was discussed and courses in diagnosing and troubleshooting were developed. Wireless applications were developed in the cluster. The programming of tablets and smartphones (C ++ for Android), known within i-MOCCA and SYSIASS, and knowledge of (wireless) networks within i-MOCCA is important information that has been exchanged and can lead to further developments in the near future[5].

4 Integrated design: design, rapid prototyping, and production code generation; all in one environment/cycle.

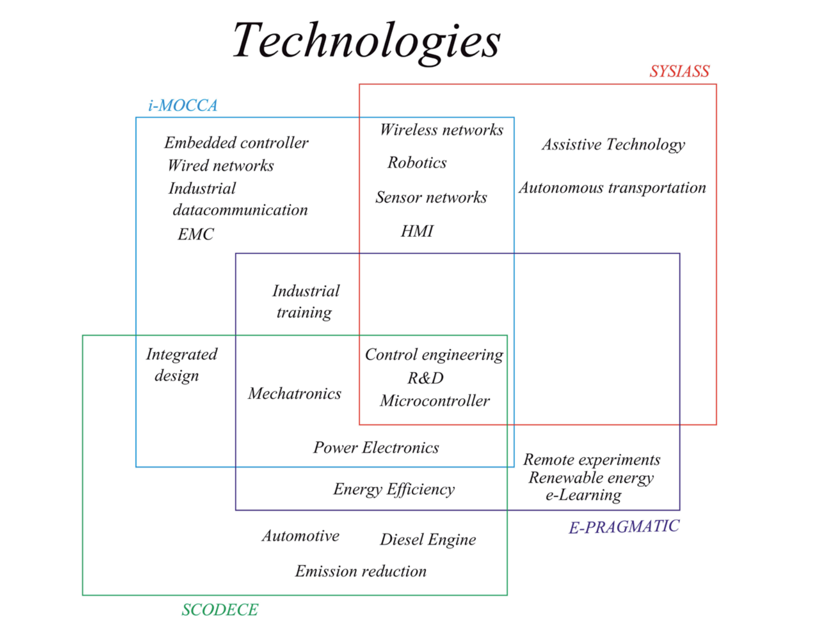


Figure 11. The diverse technologies used in the clustering projects are found to concentrate in seven key enabling technologies.

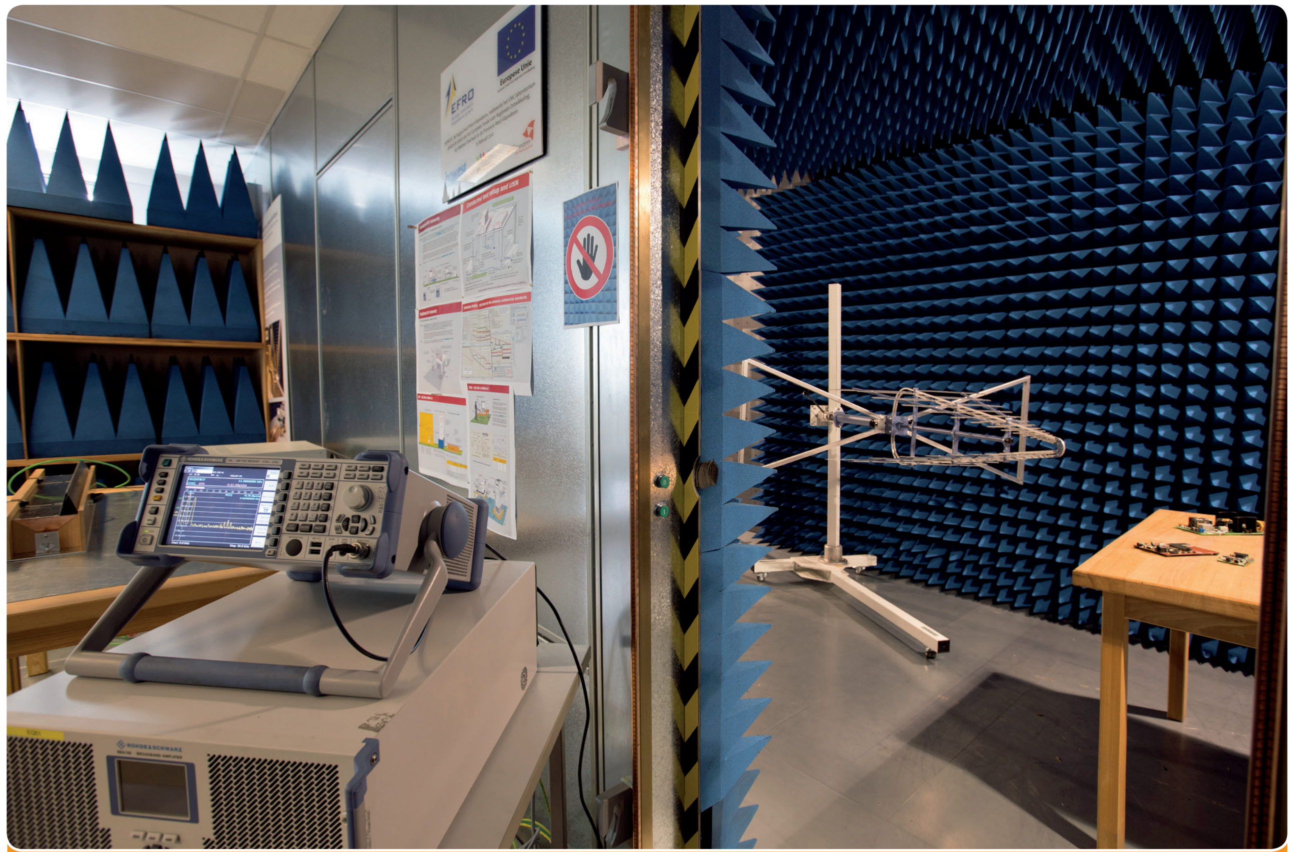


Figure 12. Anechoïc chamber with test rig, used for EMC testing.

Robustness of networks

Robustness of networks means both data security and immunity to disturbances from external electromagnetic waves. With the Internet of Things, a huge wireless mesh will connect everything. To prevent unauthorized access to information, security of the network and security of data is an important issue. Another problem is the interference coming from electromagnetic waves (electromagnetic interference). Interference can disturb data communication, causing failures of critical systems. Standardization and compatibility levels are important to maintain the current gap between emission and immunity. Within the project i-MOCCA electromagnetic compatibility has become an elaborated topic (Fig. 12). In the Phase 2 proposal, this knowledge is exported to other projects, in particular for testing the robustness of assistive technology (SYSIASS) and the influence of external fields on communication and instrumentation (all partners).

5 For the near future, a first study and demonstrator are planned, applied to a powered wheel chair and to small LEGO mobile robotics.

HMI – Human-Machine-Interface

Human-machine-interfaces need to be created from the viewpoint of the user. For industrial appliances, tablets and smartphones will be more extensively used, asking for more robust and reliable systems. For disabled people the HMI is sometimes the only way that they have to interact with their environment. Since 2010 and thanks to the tablet, new solutions, at affordable price, have been offered to disabled people to allow them to control their environment or communicate with other people. For example, using a tablet or a smartphone and a wireless connection (Infrared, WiFi or Bluetooth), it is possible to open or close the door, control the light, the temperature, the TV or the music device. These apps could also be controlled by the joystick of the powered wheelchairs.

The HMI could be also a solution for people who are not able to drive the powered wheelchair using a joystick. They can control their wheelchair by speech using a microphone, by head control or by combined gesture and facial movements using a webcam.

The programming of tablets and smartphones (C ++ for Android) to communicate between man and machine is a component of SYSIASS. HMI is also a component in i-MOCCA, albeit in industrial and building automation applications (Fig. 13).

e-Learning

New technologies require training and lifelong learning. Given the complexity of the systems to teach, courses are required about simulated and remote environments. Within the project E-Pragmatic knowledge was gained on the development of remote experiments and the development of digital courses. The other project partners can use this knowledge to expand the group of available courses with their knowledge and laboratories.

e-Health

e-Health refers to health care, supported by electronics, sensors and communication. An example in this area is continuous monitoring of patients using wearable sensors. The evolution is that sensors are embedded in textiles, so that the patient is not hindered, and not even aware of these sensors. The current trend is that the sensors are completely autonomous. Recent sensors contain a wireless communication device, a power source and a microcontroller. This limits the need for connections and wires and increases the robustness of the system. Optionally the sensor data can be logged, which can be read by special equipment, but here also the trend is to exchange the data continuously with mobile devices such as the smartphone.

Assistive technology

Assistive technology covers the technical tools that are used to increase, maintain, or improve the functional capabilities of specific target groups. Examples of target groups include people with disabilities, but also the elderly. Technological developments, such as service robotics, ensure motoric support. The apps developed for the smartphones give a communication support. An example is the Android-based application (Fig. 14) designed to give people who are temporary or definitely unable to speak the ability to make calls. The operation is performed using the smartphone keyboard. The message is directly transmitted to the interlocutor within the call through the speaker. This allows for real-time communication. Word or message libraries can be configured in advance to ease the communication.

Sensor technology serves for sensory support and communication. An example for the elderly is the use of wireless sensors for fall detection and communicating automatically to a central alarm. In SYSIASS, the possibility to drive the powered wheelchair by using the tongue was investigated. The tongue position is measured thanks to a tongue touch RFID-tag (Fig. 15).

Figure 13. Android solution for environment control proposed by Domodep http://www.domodep.com/ .

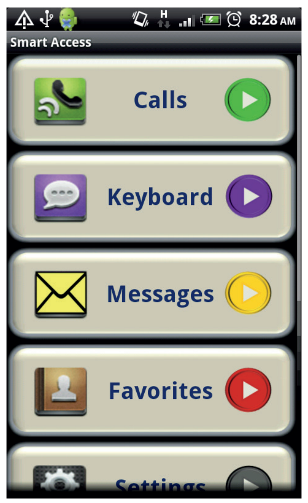


Figure 14. VoiceSmartAccess app developed by ISEN-Lille, France.

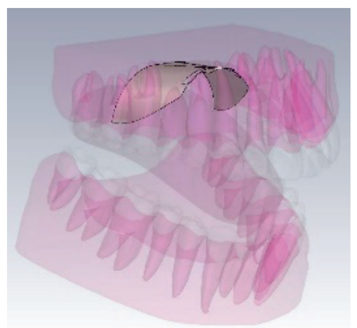


Figure 15. Modeling of mouth for the Tongue Touch RFID Tag developed by University of Kent, UK.

Integrated design

Systems become more complex, in a way that only simulations can test the behavior of an algorithm or device under all circumstances. Traditional development of a product will test the first time on the first prototype to see if the specifications are met. When a deviation is noticed, redesign requires time and a lot of money. That is why the industry introduced "model based" design, leading to "integrated design" (Fig. 16). Every step of the development is now simulated (hardware, software, algorithms). A step further is cosimulation where mechanical, hydraulic, thermal, … simulation software works with mathematical software to visualize the simulation and control.

Embedded systems and controllers

The cluster project partners all extensively used Matlab and Simulink for modeling, simulating and developing algorithms. These algorithms were programmed in microcontrollers and embedded controllers. Code generation was done via Matlab to program these algorithms in hardware-in-the-loop targets. Hardware-in-the-loop uses mathematical presentations of plants to simulate dynamic systems. The plant creates virtual sensor data and feeds these to the embedded controller. The algorithm under consideration is programmed ("designed" in fact) using Matlab and implemented in an embedded controller. In this way the behavior of the plant can be optimized, without the need of a real plant. In SCODECE also Software-in-the-loop was examined as they focused mainly on algorithms; i-MOCCA also linked Matlab algorithms to industrial hardware targets and fieldbuses.

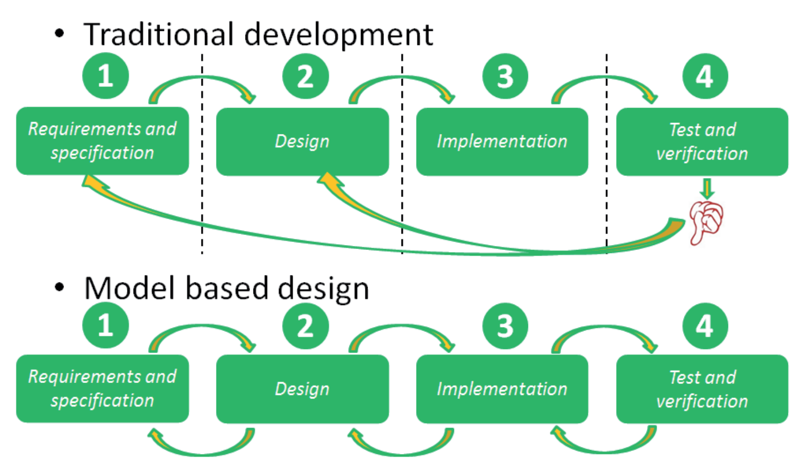


Figure 16. Direct feedback in every production step is possible using integrated (model based) design.

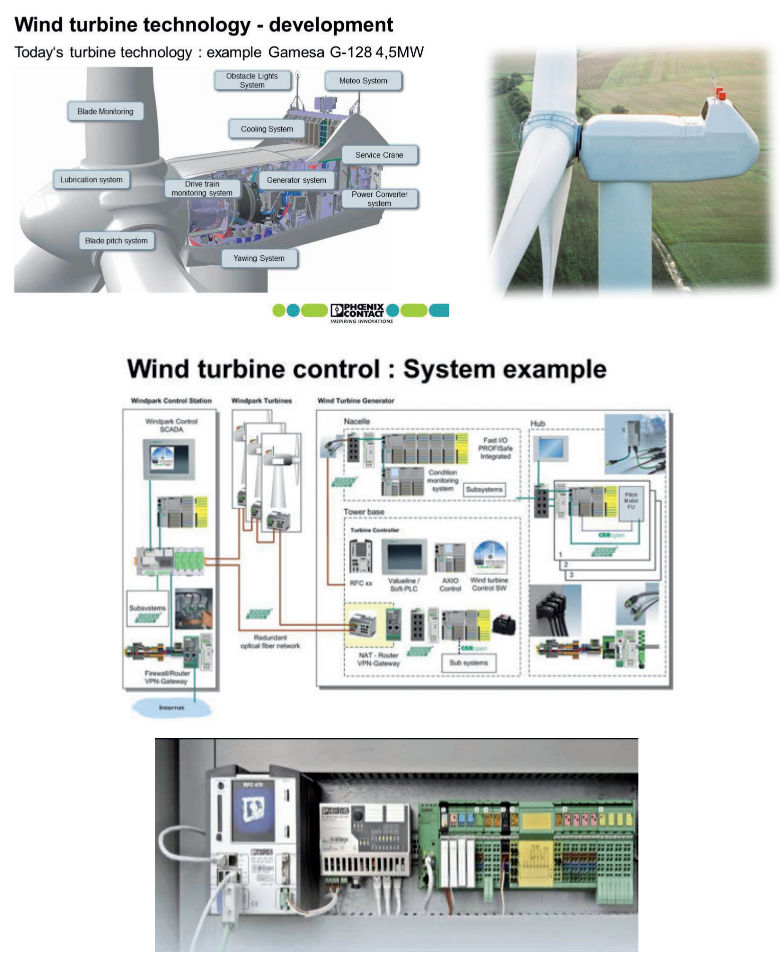


Figure 17. Wind generator of Gamesa with technology from Phoenix Contact, using robust standard industrial networks, controllers (PLCs), and translation of control design in Matlab & Simulink directly to real-time code.

Reference: lecture "Wind generator pitch control using PROFINET and industrial embedded control", Philipp Dauer, Phoenix Contact. (i-MOSYDE cluster conference, 21/10/2014, Gent, Belgium)

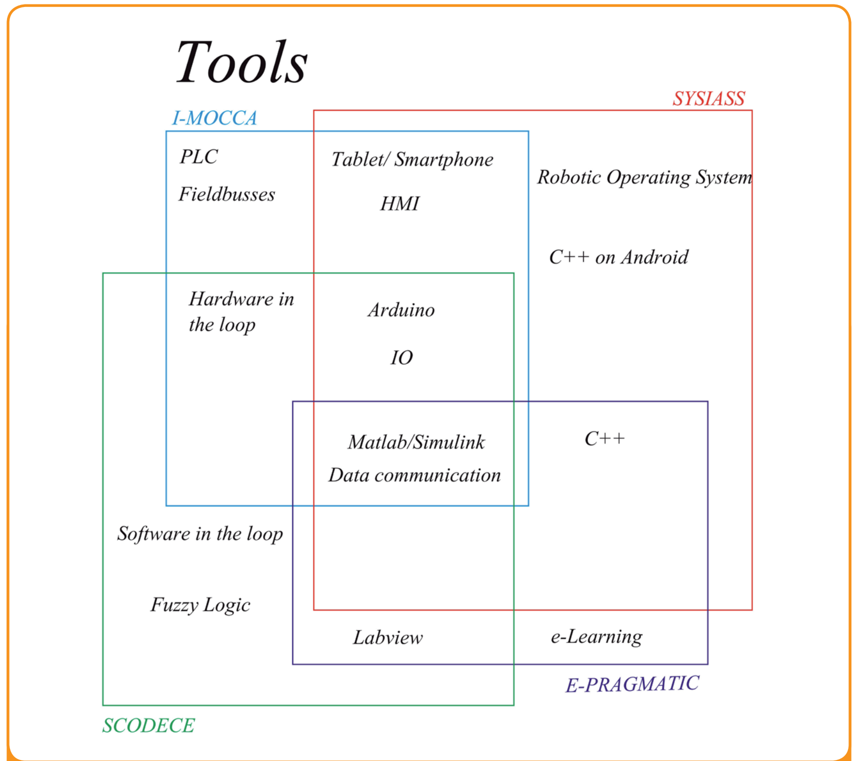


Figure 18. Within the cluster, a rich environment of tools is used; the contributing projects show a large resemblance in used tools, already present before the actual clustering.

Fig. 17 illustrates a large scale green application for wind generator control, combining integrated design, industrial embedded controllers and robust networks.

2.3 i-MOSYDE – Towards MOdern SYstem DEsign

When the above elements are examined, all cluster partners possess the knowledge of a number of key elements of these technologies. The cluster makes it possible to combine all these facets to develop intelligent modern systems, leading to Cyber Physical Systems, that are part of the Internet of Things, smart factories, Industry 4.0, … .

In i-MOSYDE we have identified 3 themes that in our opinion, and with our interests and expertise in the key enabling technologies described earlier, are interesting to explore.

1) Wireless and mobile wireless technology used for control (e.g. in industrial networks) and interfacing (human-machine, machine-machine, …) using smart phone, tablet or PC.
2) The "Internet of Things" (with many acronyms (and application domains), like Industry 4.0, Smart Factories, e-Health) needing not only data communication but also extensive diagnostics, robust EMC compatible design, …
3) Integrated design for embedded control: from R&D in e.g. Matlab & Simulink to (production) program code generation for the appropriate hardware target, combining control, data communication for connecting sensors, actuators and HMI, and diagnostics.

These 3 themes, paradigms (distinct, new concepts), describe fast developing technologies that are needed in a variety of fields, ranging from smart factories, smart assistive technology, cleaner (hybrid) engine control, building automation, e-learning, and that will lead to more **I**ntelligent **MO**dern **SY**stem **DE**sign.

In the near future, the i-MOSYDE project partners hope to jointly perform short practical evaluations of these themes. In the longer term, projects tackling these themes can effectively support industry, economy and society; interest on these themes has proven to be very large, as the massive interest and cooperation on the cluster conference has shown (Fig. 20, Par. 3.1).

Short term practical evaluations could include:

- Combining mobile HMI on smart phones or tablets to implement a safety stop called by supervisors to safely interrupt movement of autonomous powered wheel chairs (PWC), or, as test platform, autonomous moving LEGO mobile robotics[6].
- Making PWCs, engine test platforms, … more robust for EMC and testing their communication lines.
- Applying integrated design methods to greener hybrid engine motor control design.

6 In this case also combined with "integrated design".

CHAPTER 3

Some applications and beneficiaries of key enabling technologies

3.1 Beneficiaries

i-MOSYDE covers a broad spectrum of beneficiaries, given the fact that we work on basic "enabling" technologies that can be applied in a very wide range. Fig. 19 tries to give an overview; this kind of abstraction and simplification inherently has inaccuracies, but it clearly illustrates the fact that trends and paradigms discussed earlier have an impact on many aspects of the (industrial) economy and society. We illustrate this with some examples in 3.2 . The large participation to the cluster conference is also an illustration (Fig. 20).

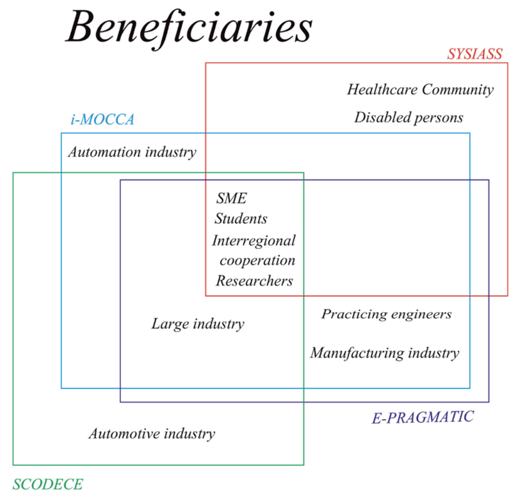


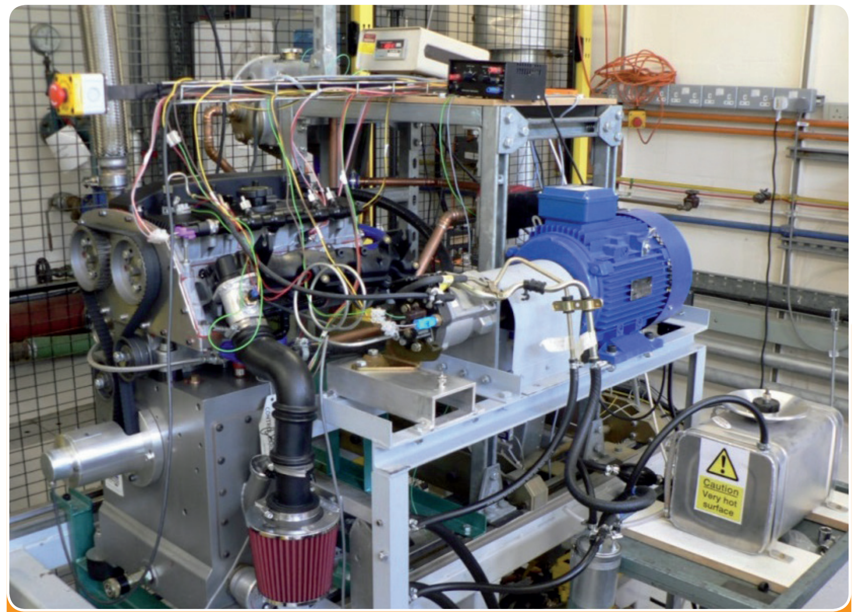
Figure 19. The cluster targets SMEs and large industry, but also students, practicing engineers (very important in supporting existing industry), and R&D, with applications also reaching healthcare and disabled persons.

Figure 20. Over 200 people from industry, universities and professional organizations actively participated to the i-MOSYDE cluster conference.

3.2. Applications of the key enabling technologies

3.2.1 Integrated design for a clean engine test platform

The road transportation sector plays a crucial role in the modern economy, but this type of transportation is also largely responsible for environmental problems. In 2008 more than 20% of CO2 emissions in Europe can be related to road transportation against 2% for other types (ship, aviation, railway). In road transportation, diesel engines share around 50% of the new vehicle market due to their low fuel consumption but remain high pollutant compared to other types of engines.
As bio-fuel is an alternative to fossil fuel for improving the global warming problem, the EU aims to increase the share of bio-fuels in transportation. In the project SCODECE, a new control and monitoring system is developed, that allows the diesel engine to operate with low temperature combustion under high load conditions. Low Temperature Combustion (LTC) under high engine load is problematic due to unacceptable exhaust of NOx. With advanced control technology Variable Valve Timing (VVT) is optimized to lower the emissions of NOx with more than 20% and reduce the fuel consumption by 10%.
A test bench is developed for a bio-diesel engine operating in LTC mode at high load that serves as an expertise platform for industrial users and a research promoting platform for academic partners (Fig. 21). A virtual simulator reproducing the functioning of bio-diesel engine is also developed to technically and economically optimize the system.
The system is controlled with a real time fuzzy logic controller and an adap-



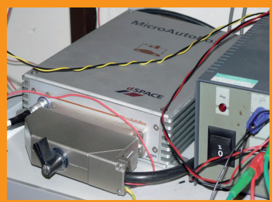
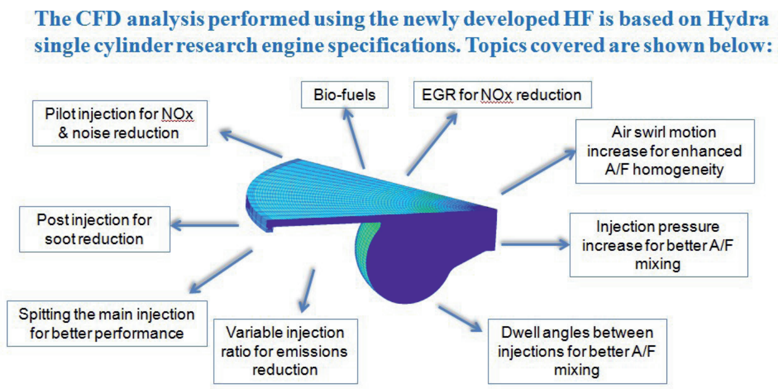


Figure 21. Reducing "soot" and NOx, improve engine efficiency thus reducing fuel consumption and CO2 emission; R&D directly linked to the EU 2020 goal of reducing greenhouse gas emissions. (Clockwise: diesel engine test stand, embedded controller, strategies for reducing emission.)



tive fuzzy logic controller. Software-in-the-loop and hardware-in-the-loop are tested with Matlab, Simulink and hardware targets. Co-simulation is established with the simulation modeling software AmeSim. Cooperation in the cluster focuses on the use of embedded controllers and EMC-aware design of the setup. Further implementation can be based on embedded controllers including FPGAs, programmed by Simulink generated code.

The direct beneficiaries from this work are firstly all partners involved in the project. The EU industrial companies belonging to the user group, including Technord (BE), CRITT M2A (FR), LMS (FR), CERTIA (FR), Lemon (UK), will also benefit from the research results. Environmental organizations such as ADEME can make use of the data in the research results for regulation making and action taking.
http://www.scodece.org

3.2.2 Assistive technology: device ensuring safe navigation for powered wheelchairs

Assistive Technology can be defined as any service or device which has been designed for the purpose of aiding the disabled and the elderly to maintain their independence. An example of assistive technology is the devices providing assistance to people using a powered wheelchair, helping them to avoid collisions whilst maintaining control over the technology without taking over control. This device is interfaced with most commercial wheelchairs.

One example of such a device is the one guaranteeing a safe navigation (Fig. 22). It uses low costs sensors such as ultrasound (this kind of sensors is also used in the cars for the parking aid) and infrared to detect the obstacles around the wheelchair. The speed of the wheelchair is reduced in function of the distance between the wheelchair and the obstacles even if the user tries to go faster. A security stop on the wheelchair is also provided in case of danger[1]. The software providing the safe navigation is embedded in an Arduino Mega board, a low cost embedded computer.

The device provides a visual feedback for the users, which helps them to understand the wheelchair behavior, in the case when it doesn't react in the way that the user drives. A box with 12 LEDs, gives information to the user about the direction and the degree of danger of the detected obstacles (Fig. 23). The same information could be provided using a tablet.

The safe navigation device helps to decrease both the number and the gravity of the potential collisions between the wheelchair and the obstacles in a day life situation. It increases the security of the powered wheelchair drivers by offering assistance for driving. The number of people who could obtain the drive license for a powered wheelchair will be increased.

The main beneficiaries of this assistive technology are the people having motor impairment and using a powered wheelchair. The occupational therapist could also use it for training purposes.

In the last decade, the EU and the Member States have stimulated the assistive technology. For example, EU's Seventh Framework Programme for Research (FP7) includes a specific program AAL (Ambient Assistive Technology) (www.aal-europe.eu) aiming the development and innovation at EU level in technologies and services for ageing well in the information society. In 2009, the French government decided that one of the axes of the national strategy of research must be the assistive technology for improving the autonomy of older and disabled people. In her Letter to the Parlia-

1 In the near future, cluster project partners hope to combine mobile wireless HMI and embedded control into an application so that supervisors of disabled people can also remotely force an emergency stop, using a standard smart phone or tablet.

Figure 22. Device for a safe navigation plugged into a wheelchair manufactured by DupontMedical.

Figure 23. Box with 12 LEDs (top) or a tablet (bottom) for visual feedback

ment on e-Health dated June 2012, the Dutch Minister for Health, Welfare and Sport (VWS) set out these opportunities, while making the point that adoption of e-Health by patients and professionals alike is a necessary condition for e-Health to succeed. The governments' overall policy is to let people live independently for longer if their homes are adapted, for example if thresholds are removed and handrails or stair lifts are fitted. Commissioned by the Department of Health and presented to UK Parliament each July, the Foundation for Assistive Technology (FAST) reports on Assitive Technology research and development activity across the UK, for the past 15 years. Providing a comprehensive report on all AT research being funded by the UK government, this is a valuable resource for the sector.

3.2.3 e-Learning: a modern way of sharing knowledge in sustainable energy and mechatronics

With the increasing role of sustainable energy and mechatronics also a need for high-skilled workforce to support the industry growth is increasing. To further support this growth not only regular education is important, but also a lifelong learning of the professionals in the industry is of great importance. In many companies the employees are educated within conventional in-house training, which is however mostly provided by the producers of the manufacturing equipment. As such it fails to give broader knowledge in new, emerging technologies and doesn't foster innovative ideas. By the cooperation of universities and industry this can be changed. The activities of the E-PRAGMATIC network are aimed to provide the electro-mechanical industry an integral solution to improve their in-company training. Further, the direct cooperation of industry and universities enables bi-directional transfer of knowledge and also supports research cooperation.

The main beneficiaries of the E-PRAGMATIC network are practicing engineers and professionals from the industry, especially the older age groups, who don't have knowledge about the new technologies although this is more and more requested at their workplaces. E-PRAGMATIC integral learning solution (learning portal, 21 e-learning modules developed for the needs of industry and adult lifelong education) enables them to obtain this knowledge in such way that the learning activities can be integrated into their everyday life.

Addressed are following EU objectives and priorities within lifelong learning programs: (1) To support improvements in quality and innovation in vocational education and training system, (2) To improve the quality and to increase the volume of co-operation between institutions, (3) To support the development of innovative ICT-based content, services, pedagogies and practices.

In order to match offer and demand, an "industrial education needs" analysis was conducted in the countries involved in E-PRAGMATIC. To obtain the necessary data, two questionnaires were developed, one for the employees and one for the management of the companies. 285 responses were obtained from the employees and about 50 from the companies' management.

The results of this survey are interesting for the cluster, as education and lifelong learning are valid for all engineers and higher technicians. Internet sources are mostly used, but also professional information in different formats (journals, seminars, training) is widely used. To combine the benefits, E-PRAGMATIC combined internet education with supervised distance education.

The results were further used to develop an integral training solution for industry, which consist of four elements:

- a learning management system
- design of learning material for the highest learning efficiency that enables learning from the screen
- education approach suitable for professionals from industry
- training modules and programs from mechatronics and sustainable energy, as shown in Fig. 24.

The "e" should be interpreted to mean "exciting, energetic, enthusiastic, emotional, extended, excellent, and educational" in addition to "electronic." (Bernard Luskin, pioneer of e-learning)

One of the very popular courses is "Solar Electricity" developed by Delft University of Technology. The module delivers basic knowledge of solar electricity. First solar module characteristics are analysed (and measured on distance laboratory). Solar cells from modules to arrays are explored and problem of shading explained. Different converters for grid connection of solar cells are proposed and the basic principle of maximum power point tracking is explained. Fig. 25 shows an example of the learning atom from this module.

For obtaining some practical knowledge a distance laboratory is available.

The integral approach was tested by international pilot training, where about 200 professionals from industry have participated. This very successful training showed that the time and space independency of distance education are very much appreciated. They prefer supervised distance education, where supervisors support them during the learning process. Also pilot training has confirmed that sustainable energy is one of the most important training topics in the industry at the moment.

Training methods developed and verified within the network are applicable in the in-company training of enterprises in the related fields. Both university and industry profit from practical experiences and knowledge acquired using the innovative hypermedia e-content and advanced learning environment.

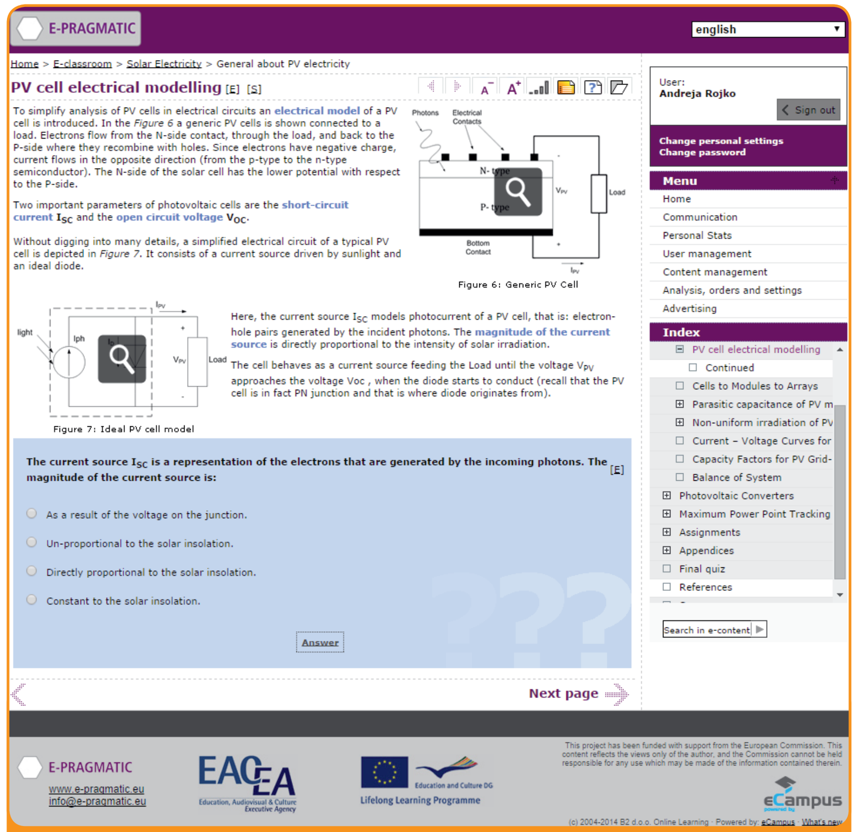


Figure 25. Learning atom from 'Solar electricity' training e-learning module.

Training program	Included e-learning modules
General mechatronics	Electrical circuits, Applied control theory, Electric drives, Mechatronic devices
Robotics	Mechatronic devices, Introduction to industrial robotics, Robot programming, Wheeled mobile robots
Microcontrollers	Introduction to Microcontrollers, 8-bit Microcontrollers Advanced Course, Low-cost platform to provide LAN/WAN connectivity for embedded systems
Computer-based measurements	Introduction to LabVIEW and Computer Based Measurements, Computer-based Measurements and Instrument Control
Electric and hybrid vehicles	Energy and energy storage in electric cars, Power electronic for electric vehicles, Hybrid drive
Alternative technologies	Solar electricity, Hybrid drive, Energy efficient drive technologies
Engineering software/tools	Introduction to LabVIEW, Introduction to Microcontrollers, PLC controllers and industrial networks
Materials	High temperature design
Distance training	Introduction to remote and online engineering

Figure 24. Developed training programs and e-learning modules.

General conclusion

In the cluster, interregional collaboration was deepened and now comprises a broader group of project partners. The thematic clustering allowed further exchange of ideas, and a closer look at potential further developments.

In this first phase of the cluster, the partners looked with a broad view at "intelligent modern system design". A very successful interactive thematic conference, more than 200 attendants (the large majority from industry), our website and this publication are – in this phase – our information channels to the stakeholders.

The partners discussed the lessons learnt, both on creating a successful interregional project and on technical-scientific topics.
Seven key enabling technologies in the fields of interest have been identified by the cluster. In the near future, the whole group of cluster partners hopes to engage work in smaller groups on 3 themes (sub-items), gaining initial experience and producing first pilots and demonstrators.

The combined result of this activity will produce "a peek into the future", several jointly realized case studies on interdisciplinary technologies and small demonstrators, small steps further indicating technological, research and educative challenges for the future.

The "interconnected smart world of things and services" promises to create a competitive industry, a greener economy, and an inclusive society. The necessary technologies exist or emerge, but the challenge is to implement and combine everything into an optimally working interconnected system. The complexity of this asks for research, education and a clustering of engineering disciplines.

While working on it, while experiencing the changes, we – both as researchers and as a society – will take small steps in the evolution towards a (more) digital society. Things will not happen overnight, but we will have grown to a smarter, more sustainable, more inclusive industry, economy and society. Looking back in 10 or 15 years, maybe a revolution after all !

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